Contemporary results of juxtarenal aneurysm repair

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Objective: **The increasing use of aortic endografts predictably will add to the complexity of open abdominal aortic aneurysm (AAA) repair and, therefore, the proportion of surgically treated infrarenal AAAs that are juxtarenal in location (JRA) will grow. This study reviews a single-center experience with JRAs.**

Methods: **Between June 1994 and December 2000, 138 patients underwent elective repair of a JRA, comprising 16.1% of 859 consecutive asymptomatic and intact symptomatic nonruptured infrarenal AAAs repaired over the same period. All patients with JRA needed proximal suprarenal clamping (SRC) or supravisceral (SVC) clamping. Patient demographics, selected risk factors, and operative details were recorded. Univariate analyses of selected risk factors for an adverse perioperative event were assessed, and multivariate analyses were performed with linear and logistic regression with backwards selection.**

Results: **SRC was used in 95 patients (69%), and 43 patients (31%) underwent SVC. The mortality rate was 5.1% (7/138) for JRA repair, and 2.8% (20/720) for infrarenal AAA repair ($P = .03$). The mortality rate was significantly greater for those patients who received SVC compared with SRC (11.6% versus 2.1%; $P = .02$). Multivariate analysis identified SVC position as the only independent predictor of mortality (odds ratio [OR], 6.1; 95% CI, 1.1 to 32.9; $P = .035$). Transient renal insufficiency occurred in 39 patients (28.3%), but only eight patients (5.8%) needed dialysis. Patients who had SVC had a significantly greater rate of renal insufficiency than those who received SRC (41.9% versus 22.1%; $P = .02$). Multivariate analysis showed SVC position (OR, 3.3; 95% CI, 1.4 to 7.8; $P = .008$), diabetes (OR, 3.7; 95% CI, 1.1 to 12.9; $P = .04$), and preoperative renal insufficiency (OR, 5.8; 95% CI, 2.2 to 15.4; $P < .001$) were independent predictors of postoperative renal insufficiency. Renal ischemia during proximal clamping cannot alone explain renal complications because clamp time was shorter in patients with SVC (24.9 ± 2.4 minutes versus 32.2 ± 1.5 minutes; $P = .009$).**

Conclusion: **JRA repair can be accomplished with a low mortality rate, but a more proximal clamp position may adversely affect outcome in these patients. Postoperative renal insufficiency is related to diabetes, preoperative renal insufficiency, and SVC position. These results suggest SRC is safer than SVC for proximal aortic clamp control of JRAs. Although clamp level must be tailored to patient anatomy, outcome may be improved if the clamp level can be kept distal to the superior mesenteric artery origin. (J Vasc Surg 2002;36:1104-11.)**

The technical details of juxtarenal abdominal aortic aneurysm (JRA) repair require operative strategies that are more complex than routine infrarenal abdominal aortic aneurysm (AAA) repair. The potential deleterious effects of both suprarenal and supravisceral aortic cross clamping have previously been elucidated and include ischemic nephropathy,[1] visceral ischemia/reperfusion injury,[2] embolization, and coagulation disorders.[3] Some authors have advocated different approaches to facilitate a safer repair, such as retroperitoneal exposure,[4,5] or routine supraceliac cross clamping[6] to avoid dissection and clamping around the renal arteries.

Combined results for both conventional open surgical suprarenal and JRA repairs previously have been reported,[7-9] and our own results for suprarenal AAA repair have been reported as part of a large thoracoabdominal aneurysm series.[10] However, few reports specifically analyze outcome data from infrarenal AAAs that are juxtarenal in location and require supravisceral or suprarenal cross clamping. With an increasing number of infrarenal AAAs being repaired with endoluminal stent grafts, the next hurdle will be to perfect JRA repair through minimally invasive techniques. We sought to evaluate our results with suprarenal clamping (SRC) and supravisceral (SVC) aortic clamping for JRA repair, to compare different clamp locations, to identify factors predictive of outcome, and to provide baseline data for future stent graft comparisons.

METHODS

From June 1, 1994, to December 31, 2000, all patients who underwent infrarenal AAA repair by members of our department were prospectively entered into a computerized database. This study had approval of our institutional review board. Operative notes were reviewed for cross-clamp location, and data then were gathered through review of the medical record. An aneurysm was considered juxtarenal if it encroached on the renal arteries (but did not include the renal arteries), had no suitable neck for clamping, and required either a suprarenal or supravisceral cross

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clamp for proximal control. Excluded were type IV thoracoabdominal aneurysms, suprarenal/pararenal aneurysms, patients with polar renal arteries, and ruptured aortic aneurysms. Aneurysms were evaluated with computed tomographic or magnetic resonance imaging scans and aortic angiography.

A total of 859 consecutive open surgical procedures were performed to repair infrarenal AAAs during this period. One hundred thirty-eight patients (16.1%) needed SVC or SRC and serve as the study group, of which 17 (12.3%) were symptomatic and 121 (87.7%) were asymptomatic. One hundred twenty-five of the aneurysms (90.6%) were degenerative/atherosclerotic aneurysms, and 13 (9.4%) were inflammatory aneurysms. All patients received intraoperative heparin; mannitol, furosemide, and low-dose dopamine were routinely used for renal protection.

Outcome assessment and statistical methods. Patient demographics analyzed were age, gender, size of aneurysm, coronary artery disease (CAD), previous coronary artery bypass or percutaneous coronary angioplasty, history of chronic obstructive pulmonary disease (COPD), renal failure, hypertension, diabetes, and symptoms related to the aneurysm. The intraoperative details reviewed were: clamp location, clamp time, concurrent renal artery endarterectomy or bypass, type of repair (aortobiiliac, aortobifemoral, or tube graft), surgeon, and exposure (retroperitoneal versus transabdominal).

The primary outcome measurements analyzed were: in-hospital or 30-day mortality, postoperative renal insufficiency, dialysis dependence, myocardial infarction, pulmonary failure, return of bowel function, blood products transfused (total products, packed red blood cells [pRBCs], fresh frozen plasma [FFP], and platelets), hospital length of stay, and intensive care unit (ICU) length of stay. Complications are reported according to previously established guidelines.[11] Renal insufficiency was considered if any postoperative creatinine level was greater than 1.8 mg/dL or, in the case of underlying renal insufficiency, a 50% increase above the patient's preoperative baseline. Only one patient was on dialysis before surgery. A compilation of total pulmonary complications included prolonged postoperative intubation period (>48 hours), the need for reintubation, or positive sputum culture and radiographically confirmed pneumonia. Myocardial infarction was defined as an elevation of creatinine phosphokinase or troponin I levels and concomitant electrocardiographic changes.

Waldon's χ^2 test and Fisher exact test were used to assess the association between clamp type and preoperative, intraoperative, and postoperative categoric variables. Wilcoxon rank sum test and unequal variances *t* test were used to assess the univariate association between clamp type and preoperative, intraoperative, and postoperative continuous variables. Logistic and linear multivariate regression models with backwards selection were used to assess the association between selected risk factors and outcomes, adjusting for possible confounders amoung the preoperative and intraoperative variables. Continuous outcomes were log transformed to better meet model assumptions.[12] All tests were performed at a significance level of .05 with SAS 8 software (SAS Institute, Cary, NC).

Table I. Demographic data

		SVC	*SRC*	P *value*
No.	138	43 (31%)	95 (69%)	
Age* (y)	71.7 + 0.6	72.3 ± 7.9	71.4 ± 6.9	.52
Aneurysm size* (cm)	6.4 ± 0.1	6.6 ± 1.3	6.4 ± 1.3	.39

*Mean ± standard error.

RESULTS

The average number of JRAs performed each year was 21.2 (16%); however, the number of patients who needed SVC or SRC as a proportion of total open surgical infrarenal aneurysm repairs steadily increased over this period from 10.8% in 1995 to 31.7% in 2000. Of the JRAs reported in this series, 56% were repaired with aortic tube grafts, 42% with aortobiiliac grafts, and 2% with aortobifemoral grafts. Baseline demographics for SVC and SRC are summarized in Tables I and II. No difference was seen between the groups with respect to age, size of the aneurysm, gender, history of CAD, previous coronary intervention (coronary artery bypass or percutaneous coronary angioplasty), diabetes, hypertension, COPD, preoperative renal insufficiency, or aneurysm symptoms.

No difference was seen between groups with respect to operative exposure (retroperitoneal approach, 57.6%; versus transabdominal approach, 42.4%; $P = .69$). A total of 26.8% of JRAs repaired underwent a combined renal artery procedure. Thirty-five percent of patients who had SVC underwent a combined renal artery procedure, compared with 23.2% of those who had SRC, but this did not reach statistical significance ($P = .16$). Despite a greater number of simultaneous renal artery procedures, the average clamp time in patients who received SVC was 24.9 ± 2.4 minutes, which was significantly less than the 32.3 ± 1.5 minutes in those who received SRC ($P = .009$).

In-hospital outcome data are provided in Table III. No difference was seen between groups with respect to hospital length of stay, ICU length of stay, return of bowel function, total blood products transfused, and pRBCs transfused. The median number of units of FFP and platelets transfused were significantly greater in those patients who received a SVC compared with SRC.

Complications are depicted in the Fig. No difference was seen between groups with respect to pulmonary complications, incidence of dialysis dependence, and myocardial infarction. The overall incidence rate of renal insufficiency was 27.5%. Patients who received a SVC were more likely to have postoperative renal insufficiency compared with those who received SRC (41.9% versus 22.1%). The overall mortality rate was 5.1%, with a significantly greater rate in patients with SVC (11.6%) compared with patients with SRC (2.1%). No intraoperative deaths occurred. Four

Table II. Baseline variables in SVC and SRC groups undergoing AAA repair

		Total	*Percent*	*SVC*	*Percent*	*SRC*	*Percent*	P *value*
Gender	Women	46	33.0%	15	35.7%	31	33.0%	.76
	Men	92	67.0%	28	64.3%	64	67.0%	
CAD	No	44	31.9%	12	27.9%	32	33.7%	.50
	Yes	94	68.1%	31	72.1%	63	66.3%	
Previous CABG/ PTCA	No	75	54.3%	26	60.5%	49	51.6%	.33
	Yes	63	45.7%	17	39.5%	46	48.4%	
COPD	No	83	60.1%	27	62.8%	56	59.0%	.67
	Yes	55	39.9%	16	37.2%	39	41.0%	
Renal (Cr > 1.8)	No	111	80.4%	37	86.1%	74	77.9%	.25
	Yes	27	19.6%	6	14.0%	21	22.1%	
Symptoms	No	121	87.7%	40	93.0%	81	85.3%	.18
	Yes	17	12.3%	3	7.0%	14	14.7%	
Diabetes	No	124	89/9	37	86.1%	87	91.6%	.27
	Yes	14	9.1%	6	14.9%	8	8.4%	
Hypertension	No	37	26.8%	12	27.9%	25	26.3%	.85
	Yes	101	73.2%	31	72.1%	70	73.7%	

CABG, Coronary artery bypass; *PTCA*, percutaneous coronary angioplasty; *Cr*, creatinine level.

Table III. Continuous outcomes in patients with JRA

	**Overall*	**SVC*	**SRC*	P *value*
Length of stay	8 (7, 12)	8 (6, 11)	8 (7, 12)	.52
ICU length of stay	3 (2, 4)	3 (2, 5)	3 (2, 4)	.68
Bowel function	4 (3, 5)	4 (3, 7)	4 (3, 5)	.94
Packed cells	3 (2, 6)	3 (2, 8)	3 (2, 5)	.17
Plasma	0 (0, 2)	1 (0, 4)	0 (0, 2)	.04
Platelets	0 (0, 1)	1 (0, 2)	0 (0, 1)	.04
Total products	5 (3, 10)	5 (3, 4)	4 (2, 9)	.17

*Median (25%, 75%).

patients died of multisystem organ failure, three of whom received a SVC and one a SRC. Two patients died of mesenteric ischemia, and both received a SVC. The other death in the SRC group was from a ventricular arrhythmia. The mortality rate for symptomatic patients was 5.9% and for those who underwent a renal artery repair was 8.1%.

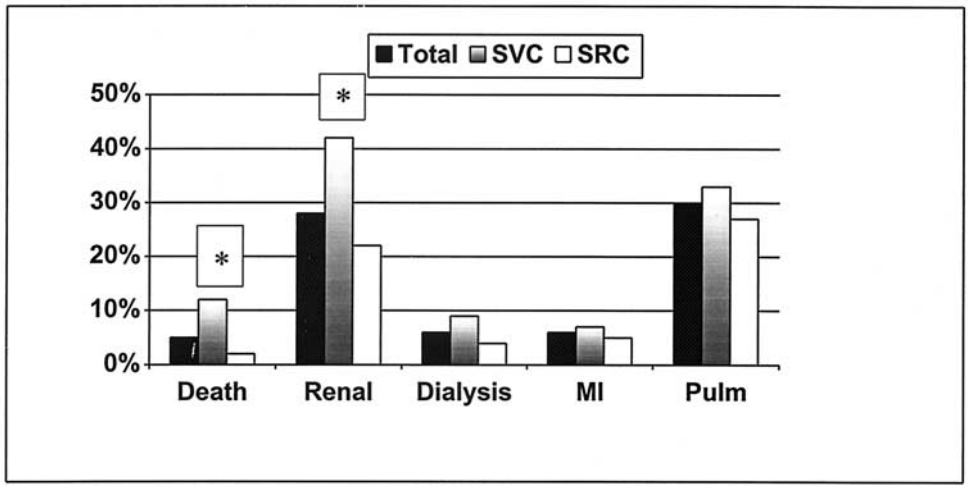
Three patients returned to the operating room for a bleeding complication, two in the SVC group (4.6%) and one in the SRC group (1.1%). One patient in each group needed reoperation for a lower extremity embolic event. Three patients in each group had pancreatitis develop, and five patients in the SVC group and four in the SRC group had elevation of hepatic serum transaminase to greater than two times normal.

Multivariate analyses with linear and logistic regression were performed to further clarify the independence of categoric and continuous factors as predictors of outcomes. The results of these analyses are provided in Table IV as odds ratio (OR) with 95% CI. The only significant predictor of postoperative mortality with logistic regression was the use of SVC (OR, 6.1; 95% CI, 1.1 to 32.9). SVC (OR, 3.3; 95% CI, 1.4 to 7.8), the presence of diabetes (OR, 3.7; 95% CI, 1.1 to 12.9), and preoperative renal insufficiency (OR, 5.8; 95% CI, 2.2 to 15.4) were all predictors of postoperative renal insufficiency, but no identifiable variable predicted postoperative dialysis dependence.

Patients who were advanced in age greater than 70 years (OR, 1.2; 95% CI, 1.1 to 2.0), patients who had a history of COPD (OR, 1.4; 95% CI, 1.1 to 2.0), and those who had preoperative renal insufficiency (OR, 1.4; 95% CI, 1.1 to 1.8) had an increased likelihood with linear regression of receiving multiple blood products. Patients who were advanced in age greater than 70 years (OR, 1.2; 95% CI, 1.1 to 2.0), who had COPD (OR, 1.5; 95% CI, 1.1 to 2.0), or who had preoperative renal insufficiency (OR, 1.4; 95% CI, 1.1 to 1.8) were also more likely to receive pRBCs. If symptoms were present, a patient was more likely to have a longer length of stay (OR, 1.5; 95% CI, 1.1 to 1.8), but no significant association was seen between factors analyzed and ICU length of stay, postoperative pulmonary failure, myocardial infarction, or return of bowel function.

DISCUSSION

At present, 60% of infrarenal AAAs are estimated to be candidates for repair with an endovascular stent graft, and therefore, the percentage of JRAs repaired with open techniques will increase.[13] Our data support this as the percentage of JRAs repaired at the Cleveland Clinic in 1995 was 10.8% but in 2000 rose to 31.7%. The predominant limitations that preclude implantation of an endograft are the size of the proximal neck and the location of the aneurysm with respect to the renal arteries. However, several new devices make endovascular repair of JRA and suprarenal aneurysms feasible and are under clinical investigation. We sought to review our open results to set a benchmark for comparison of future endovascular grafts. In addition, we evaluated comorbidities and intraoperative details to identify factors predictive of outcome.



Categoric outcomes (complications) in patients with JRA. *MI,* Myocardial infarction; *Pulm*, pulmonary. *$P < .05$.

Table IV. Multivariate analyses of outcome (logistic and linear regression)

Outcome	*Variable*	*OR*	P *value*
Mortality	Supravisceral clamp	6.1 (1.1,32.9)	.035
Postoperative renal insufficiency	Supravisceral clamp	3.3 (1.4, 7.8)	.008
	Diabetes	3.7 (1.1,12.9)	.040
	Preoperative renal failure	5.8 (2.2,15.4)	<.001
Total blood products	Supravisceral clamp	1.3 (1.0, 1.8)	.084
	Age	1.3 (1.0, 1.6)	.024
	Preoperative renal failure	1.5 (1.0, 2.2)	.04
pRBCs	Supravisceral clamp	1.3 (1.0, 1.6)	.078
	Age	1.2 (1.1, 2.0)	.055
	COPD	1.5 (1.1, 2.0)	.015
	Preoperative renal failure	1.4 (1.1, 1.8)	.017
Length of stay	Supravisceral clamp	1.0 (0.8, 1.1)	.52
	Symptoms	1.5 (1.1, 1.8)	.002

The mortality rate for routine infrarenal AAA repairs performed at the Cleveland Clinic has been reported to be 1.2%,[14] with part of the period for this report overlapping that study. However, included in this paper are patients with symptomatic aneurysms and concomitant renal artery revascularization, both of which have expected higher complication rates. In addition, we also recently have documented similarly low mortality rates for endovascular AAA repair.[15] Mortality rates for suprarenal AAA repair have been reported to be higher than for infrarenal AAA repair,[6,7,10,16] likely because of the increased complexity of the repair in addition to the sequela of visceral organ ischemia and reperfusion. The JRA repair mortality rate reported in this article was significantly greater than the infrarenal AAA repair mortality rate (5.1% versus 2.8%); however, no difference was seen in mortality rate if one considers only those patients who had a SRC (2.1%). Several factors contribute to the aforementioned differences, including cross-clamp time, clamp location, and embolization. Of all the factors analyzed in this cohort, only clamp location (SVC) turned out to be a significant predictor of mortality. These results are similar to those reported by the San Francisco group,[7] but different than reported by Green et al.[6] In Green's study, the mortality rate for JRA was 15.3%. However, their results are skewed by the fact that most of the SRC difficulties were in those patients who initially had an infrarenal clamp, which was abandoned for a SRC when intraoperative difficulties were encountered. We did have one patient with a similar fate in our series, with an infrarenal clamp abandoned for a SVC after difficulty with the proximal neck was encountered.

This article has the inherent drawbacks of a retrospective review. As such, a selection bias undoubtedly exists between where to place the proximal clamp, and therefore, patients with more difficult aortic anatomy were more likely to receive a SVC. In addition, because this study is retrospective in nature, we can only speculate why SVC has a higher mortality rate than routine infrarenal AAA repair. One possible explanation may be from referral patterns because 65% of our patients had underlying CAD, which is

much higher than other large series of JRA.[7,8,17] However, neither history of CAD or coronary revascularization turned out to be significant predictor of mortality in this report, as only one death was directly attributed to coronary disease (ventricular arrhythmia). The adverse sequelae of visceral ischemia and reperfusion injury have been reported to increase with clamp times greater than 40 minutes[18] after thoracoabdominal aneurysm repair, but our clamp times on average were well under this period and were in fact were lower in the SVC group. Three of the five deaths in the SVC group were from multisystem organ failure, with two of the three resulting directly from mesenteric ischemia and the etiology speculated to be microembolic in nature. Huber et al[19] previously reported that multisystem organ failure is the most common etiology of death after infrarenal AAA repair, but when SVC and SRC are used, this likely is the result of a complex cascade of events. Seventy-one percent of the patients who died (5/7) had dialysis-dependent renal failure develop, which has previously been associated with increased mortality after SVC.[20] The ensuing coagulopathy that results from visceral ischemia has been well documented,[21] and two of the five who died in the SVC group needed reoperation for bleeding.

Certainly, not every patient with a JRA is a candidate for SRC, as clamp location is often dictated by the amount of perirenal atherosclerosis or thrombus, in addition to the proximity of the superior mesenteric artery to the renal arteries. However, the data presented here support the preferential use of SRC, if technically feasible, as a safe method for proximal aortic control for JRAs. The greater number of cross clamps placed just above the renal arteries (compared with above the mesenteric vessels) in this series has undoubtedly been facilitated by advances in imaging techniques. Over the past two decades, tremendous improvement has been seen in computerized tomography resolution and in obtaining noncontrast and contrast-enhanced computerized tomographic scans to ascertain the degree of calcification and thrombus in the perivisceral aorta. In addition, the routine use of preoperative angiography and the results of other reports[6,7] have persuaded us to clamp above either the renal arteries or visceral arteries primarily and sooner when a difficult proximal neck is suspected.

Our rates of transient renal insufficiency were much higher than expected but are similar to the results presented in our TAA series[10] and other large-center series of JRA.[6,7,17] The percentage of patients in whom permanent postoperative dialysis dependence developed was 5.8%, which is also similar to other large series of JRA. The etiology of the renal failure is likely multifactorial as the duration of ischemic nephropathy could not alone explain the degree of renal insufficiency because the average clamp time was longer in those patients who had a SRC compared with SVC. Multivariate analysis in this report found that SVC, preoperative renal insufficency, and diabetes were all predictive of postopertaive renal insufficiency. That there was an increased likelihood of transient renal insufficiency in patients with underlying renal insufficiency or diabetes mellitus is not surprising. The causative factors for the increased incidence rate of renal insufficiency in patients with a SVC compared with SRC is not known; it is possible that in addition to ischemic nephropathy, atheroembolism or cytokine-mediated events from visceral ischemia/reperfusion may play a role.

No single factor in the mutifactorial analysis was identified to be associated with dialysis dependence, and no difference was seen between SRC and SVC for dialysis dependence. Our use of renal perfusate was variable and, in general, was used liberally when longer clamp times and renal revascularization were anticipated. The total number of combined renal artery procedures was 27%, with more patients in the SVC group (35% versus 23%) than the SRC group undergoing combined renal artery revascularization. This did not reach statistical significance and was not significant in the multifactorial model. Although the significance of adding renal revascularization procedures did not reach significance in our model, we have previously reported higher mortality rates and dialysis-dependant renal failure in patients who undergo renal artery revascularization in conjunction with aortic replacement.[22] Our preferences for renal revascularization combined with aortic replacement are to perform renal artery endarterectomy or bypass if the patient has uncontrollable hypertension on three or more medications, has a preocclusive lesion, or has ischemic nephropathy with a kidney size greater than 7 cm.

Although we did not measure specific coagulation profiles, the median units of blood products transfused and pRBCs transfused were not different for clamp location. However, SVC approached significance as a predictor of total products ($P = .17$, univariate analysis; $P = .084$, multivariate analysis) and pRBCs transfused ($P = .17$, univariate analysis; $P = .078$, multivariate analysis). Preoperative renal insufficiency was a predictor of increased total products and pRBCs transfused, with the suspected mechanism from uremic platelet dysfunction. The median number of platelets and FFP transfused was significantly higher in patients who received a SVC, but this did not turn out to be significant in the multifactorial model. The effects of SVC on the coagulation cascade have been studied extensively, with the resultant coagulopathy assumed to be secondary to enhanced primary fibrinolysis from decreased degradation of tissue plasminogen activator[21] or excessive consumption of procoagulant factors.[3] In addition, there was the need for increased transfusion of platelets and FFP in this cohort. Two of the patients in the SVC group who had a significant postoperative hemorrhage necessitating reoperation died. Unquestionably, if one can avoid the coagulopathic sequela of SVC, bleeding complications may be prevented.

In conclusion, contemporary open surgical infrarenal AAA repairs are more frequently juxtarenal in location. Although the mortality rate remains low, improved outcomes for both mortality and renal insufficiency may be facilitated with careful selection of clamp location, which is dictated by the anatomy in both the suprarenal and supra-

visceral aortic segments. When a suprarenal clamp is possible, outcome may be improved over that after SVC.

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DISCUSSION

Dr John J. Ricotta (Stony Brook, NY). This is a very nice paper from the Cleveland Clinic group with excellent results in a very difficult group of patients.

Intuitively, this does not make a lot of sense to me, so I am trying to figure out what the issues were here. And I think one of the problems is when you only have eight mortalities, which is wonderful, it is very difficult to tell what is going on between the groups. So, you may have some issues that do not come through in your analysis. It is hard for me to believe that with the short clamp times you have here that you should see the differences that you do. So, I wanted to ask you a couple of questions.

One was how you decided where to put the clamp? And the reason I am asking you this is sometimes the character of the visceral aorta, even though it is a perirenal aneurysm or a juxtarenal aneurysm, the character of the visceral aorta may be different. There may be thrombus. There may be degenerated atheroma in the visceral aorta. And it may be that the people in whom you put the supraceliac clamp in had a more diseased aorta in the visceral segment than the patients that you put the suprarenal clamp. So, I would ask you whether you have an idea about that?

The second thing you have addressed indirectly in terms of blood product requirements, but did you measure the blood loss? Do you know whether there was a difference in blood loss between the suprarenal clamp and the supraceliac clamp? And do you know whether there was increased hypotension or any sort of hemodynamic change that might explain some of either your mortality or your morbidity? There is a suggestion, again, that there was more coagulopathy in the supraceliac clamp. Again, though, your clamp times were not terribly long, so it may be just those specific patients.

Was the retroperitoneal approach, when it was used, was that a matter of physician preference?

And the final question that I have is whether you would consider using a combination of open/endovascular approaches. We just had a patient, who is 85 years old, with an aneurysm like this, and the strategy has been to do hepatorenal and splenorenal bypasses first and then put an endograft in using that neck. So, have you had any experience or would you comment on whether you think that might be a reasonable thing to do?

Dr Timur P. Sarac. Thank you for your kind comments, Dr Ricotta.

When you ask the question, how is it decided where to put the clamp, this has evolved over time. The initial impetus for reviewing clamp location came from the Rochester series published in the late

1980s, for which Dr Ricotta was a leading author. In that paper, it was recommended that all juxtarenal aneurysms have their clamp location placed above the celiac artery. However, the practice patterns at the Cleveland Clinic have been different. We preferentially place the proximal aortic clamp above the renal arteries if we encounter a juxtarenal aneurysm that cannot accomadate an infrarenal clamp. The decision making has been augmented by the introduction of endovascular stent grafts, where we are now routinely get 3-mm cuts on our CAT scans, which gives us a much better picture of the paravisceral aorta and whether there is extreme calcification or thrombus. In those scenarios, we would be more apt to place the proximal clamp at the supraceliac level. In addition, we now routinely get noncontrast-enhanced CAT scans, which gives us a very good picture of the degree of calcification in that region. With the evolution of CAT scan and dynamic CAT scans over the past 10 years, it really has been a great benefit in providing the clarity of what the aorta looks like in that area.

In addition, one of the most important points that came out of the Rochester study was the routine use of angiograms in patients with juxtarenal aneurysm. Again, this helps us determine if it is unsafe to place a suprarenal clamp and therefore immmediately go to the supraceliac aorta.

Finally, because of previous results published in the literature in the late 1980s, we now are more likely to clamp above the renals or the supraceliac aorta if it is at all suspected there is going to be some difficulty. So, we will not place a clamp on an infrarenal aorta and are more likely to move the clamp higher earlier with resultant sequela known from visceral ischemia-reperfusion, but keeping ourselves out of technical trouble within the operating room.

As far as explaining the differences in results and low mortality rates, my senior partners should be commended. Since this is a retrospective study, I can only speculate on theories and extrapolate our results. Certainly visceral ischemia-reperfusion sequela and multisystem organ failure with a supraceliac clamp are known to be greater with a supracelaic clamp than a suprarenal or infrarenal clamping. In addition, with the known coagulopathy that develops from a supraceliac clamp, this also poses problems, and particularly, we had two patients in this study die of bleeding complications who had a supraceliac clamp.

As far as blood loss, we did not actually measure the blood loss. It is difficult at our institution to give a precise amount of blood loss with the cell saver used, so this is why we used units of packed red blood cells transfused.

In addition, looking at the intraoperative variables, I did not review the anesthetic variables, so it is difficult for me to speculate on whether there were fluctuations within blood pressure upon release of clamps. I can just point out at that point that we did not have any intraoperative deaths or immediately postoperative deaths; and so, if there was difficulty, we would have really seen that much earlier on.

As for using the retroperitoneal versus transabdominal approach, my personal preference is a retroperitoneal exposure. Some of this depends on the iliac anatomy and whether concomitant renal revascularization is needed. In any event, because we are a teaching institution, we use both to allow our residents equal exposure to both approaches. If we use a transabdominal exposure for a suprarenal clamp, we more routinely mobilize the renal vein in its entire length, dividing the adrenal vein and gonadal vein and possibly the lumbar vein to allow us more proximal exposure. Exposure of the supraceliac aorta through the transabdominal approach is routine. If we use the retroperitoneal approach, frequently we will remove the eleventh rib and divide the left crus of the diaphragm for both suprarenal and supraceliac clamping.

And the last question regarded using endovascular repair for these approaches. Our group has a small experience with staged visceral bypasses prior to excluding thoracoabdominal aneurysms from dissections but used that technique for routine juxtarenal aneurysm repair.

Dr Karl A. Illig (Rochester, NY). I definitely enjoyed your talk, Tim, and it is always helpful to hear results of a nice big series like yours. As you very charitably discussed, we have extensive experience with this in Rochester, and as you know, we believe that a nice elective supraceliac clamp is a wonderful thing. Where we have run into problems is when an initially suprarenal clamp has to be shifted to a higher level because of intraoperative problems. Have you had this experience in your series? And if so, which group are you assigning them to in your paper?

Dr Sarac. Ten percent of the patients in this series were symptomatic patients. One patient out of 138 did have an infrarenal clamp, which was abandoned for a supraceliac clamp in the series, and that patient ended up getting multiple intestinal infarcts from massive embolization and expired. So, we did have just one patient with a clamp reposition in our series. Removing this patient from analyses would not have changed the results or conclusions of this study.

Dr Gary A. Fantini (New York, NY). We reported our much more modest experience with this problem at this meeting several years ago (Vasc Surg 2000;34:25-32).

My question revolves around patterns of atherosclerosis of the suprarenal and supraceliac aorta. May the clamp level in this study simply have been a surrogate marker for more severe disease at the suprarenal level such that it precluded clamp placement at that level? Similarly, may some of these patients have had an unsuccessful attempt at suprarenal clamping, such that an embolic event may have been created or a plaque fractured, prior to eventual clamp placement at the supraceliac level? In my experience, the supraceliac position is a safe and generally favorable place to occlude the abdominal aorta.

Dr Sarac. Regarding your first comment, I think both as you and Dr Ricotta have stated, there is no doubt that this is a marker for more extensive atherosclerotic disease, meaning the patients who we clamped supraceliac were certainly more likely to have a diseased aorta, whether it be atherosclerotic or thrombotic, in the perivisceral segment. And that is the reason that they were clamped supraceliac. However, the corollary is, and one of the main points we are bringing out is that a vast majority of the patients can be clamped suprarenal, and this determination is augmented with appropriate imaging. We can now identify most of the patients who we can avoid supraceliac clamping and therefore avoid the potential deleterious effects of visceral ischemia/reperfusion, embolization, and coagulopathies. Again, only one of the patients in this report had their clamp repositioned from an infrarenal to a supraceliac position, and this patient had problems.

In a retrospective study, it is difficult to compare, to say that everybody should have supraceliac clamp or suprarenal clamp when you really cannot say that. Some patients were ineligible for a suprarenal clamp because of atherosclerosis or thrombus or renal arteries too close to the superior mesenteric artery to safely place a clamp. Most of these patients were identified preoperatively with improved imaging studies. The important point that comes out is that if you can, if the preoperative CAT scan or the preoperative angiogram shows you that you can put a clamp in that area safely, our data support the San Francisco experience that the patients do better.

Dr Richard P. Cambria (Boston, Mass). Tim, it was a nice series and no one could argue with the results. I agree with Dr Ricotta's comments, with only eight deaths, the statistical message may be a bit skewed. However, if we believe the message that a supravisceral clamp was clearly associated with a worse outcome, what are your thoughts or could you comment on a compromised position? When one is approaching these aneurysms from the lateral approach, you can pick and choose where that clamp might want to go.

And my question is, given what you have discovered about the apparent impact of a supravisceral clamp location, would you explore the possibility of putting the clamp between the celiac and the superior mesenteric, which is certainly a possibility in many patients, particularly if one is in from a lateral approach?

And my second question is, you may have mentioned it in your presentation, but what was the percentage of these patients who

had some concomitant renovascular reconstruction at the time of their aneurysm repair?

Dr Sarac. The question regarding whether I would advocate placing a clamp between the supraceliac and superior mesenteric artery, I think that every patient is different and you have to use your judgment with each case. Certainly if there is a long distance of 3 to 4 cm so that it is a chip shot and you can put it between the SMA and celiac artery and you cannot safely clamp at the suprarenal level, I think it would be wise to put it there and continue visceral perfusion. However, the number of instances that that is available in my experience is infrequent.

Concerning concommitant renal revascularization, 35% of the patients in the supravisceral group actually underwent a concomitant renal artery revascularization compared with 23% in the suprarenal group. And although those numbers did not reach statistical significance, I think that that may have—all this is anecdotal—a type II error here—but I think that that certainly contributed to the increased incidence of renal insufficiency in conjunction with other factors.

Dr Bruce J. Brener (Millburn, NJ). Do you use adjuncts like pharmacologic manipulation, renal perfusion, or cooling?

Dr Sarac. Typically, if we are anticipating a prolonged clamp time or for suprarenal aneurysms or thoracoabdominal aneurysms, we will use the cooling solution that has previously been described. In this series, it is variable, and I could not pick out of the data which of the patients had it and which of the patients did not. It was sparsely mentioned in operative reports and it is more used at the surgeon's discretion.

However, our general approach is that if we are anticipating doing a renal artery bypass or a prolonged clamp time, we tend to use a renal artery cooling with perfusate. Our anesthetic regimen for intraoperative mannitol, vasodilatation, fluids, and postoperative dopamine are routine in our institution.